

US009065112B2

(12) **United States Patent**  
**Kim et al.**

(10) **Patent No.:** **US 9,065,112 B2**  
(45) **Date of Patent:** **Jun. 23, 2015**

(54) **SECONDARY BATTERY MODULE WITH SHORT-CIRCUIT PROTECTOR**

USPC ..... 429/61, 159, 161, 163, 56; 320/134  
See application file for complete search history.

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(56) **References Cited**

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U.S. PATENT DOCUMENTS

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 238 days.

5,585,207	A *	12/1996	Wakabe et al.	429/178
6,365,297	B1 *	4/2002	Wolczak et al.	429/159
2002/0070707	A1 *	6/2002	Sato	320/134
2011/0039136	A1 *	2/2011	Byun et al.	429/56
2011/0052949	A1 *	3/2011	Byun et al.	429/61
2011/0135976	A1	6/2011	Byun	
2011/0183193	A1	7/2011	Byun et al.	

(21) Appl. No.: **13/611,515**

FOREIGN PATENT DOCUMENTS

(22) Filed: **Sep. 12, 2012**

KR	10-2011-0065277	A	6/2011
KR	10-1042808	B1	6/2011

(65) **Prior Publication Data**

US 2013/0252038 A1 Sep. 26, 2013

\* cited by examiner

(30) **Foreign Application Priority Data**

Mar. 23, 2012 (KR) ..... 10-2012-0029985

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(51) **Int. Cl.**

<b>H01M 2/02</b>	(2006.01)
<b>H01M 2/06</b>	(2006.01)
<b>H01M 2/20</b>	(2006.01)
<b>H01M 2/30</b>	(2006.01)
<b>H01M 2/10</b>	(2006.01)
<b>H01M 2/34</b>	(2006.01)
<b>H01M 10/42</b>	(2006.01)
<b>H01M 10/44</b>	(2006.01)
<b>H01M 10/48</b>	(2006.01)

(57) **ABSTRACT**

A secondary battery module includes a plurality of secondary batteries, and each of the secondary batteries includes an electrode assembly, a case accommodating the electrode assembly, an electrode terminal electrically connected to the electrode assembly, a first short-circuit member electrically connected to the electrode terminal, and the first short-circuit member is configured to protrude outwardly from the case when an internal pressure of the case exceeds a preset pressure. The secondary battery module also includes a connecting member electrically connecting electrode terminals of adjacent ones of the secondary batteries, and a second short-circuit member overlapping the first short-circuit member of at least one of the plurality of secondary batteries such that the second short-circuit member contacts the first short-circuit member when the first short-circuit member protrudes outwardly from the case.

(52) **U.S. Cl.**

CPC ..... **H01M 2/1077** (2013.01); **H01M 2/206** (2013.01); **H01M 2/345** (2013.01); **H01M 10/425** (2013.01); **H01M 10/441** (2013.01); **H01M 10/482** (2013.01)

(58) **Field of Classification Search**

CPC ... H01M 2/1077; H01M 2/206; H01M 2/345; H01M 10/425; H01M 10/441; H01M 10/482

**21 Claims, 7 Drawing Sheets**

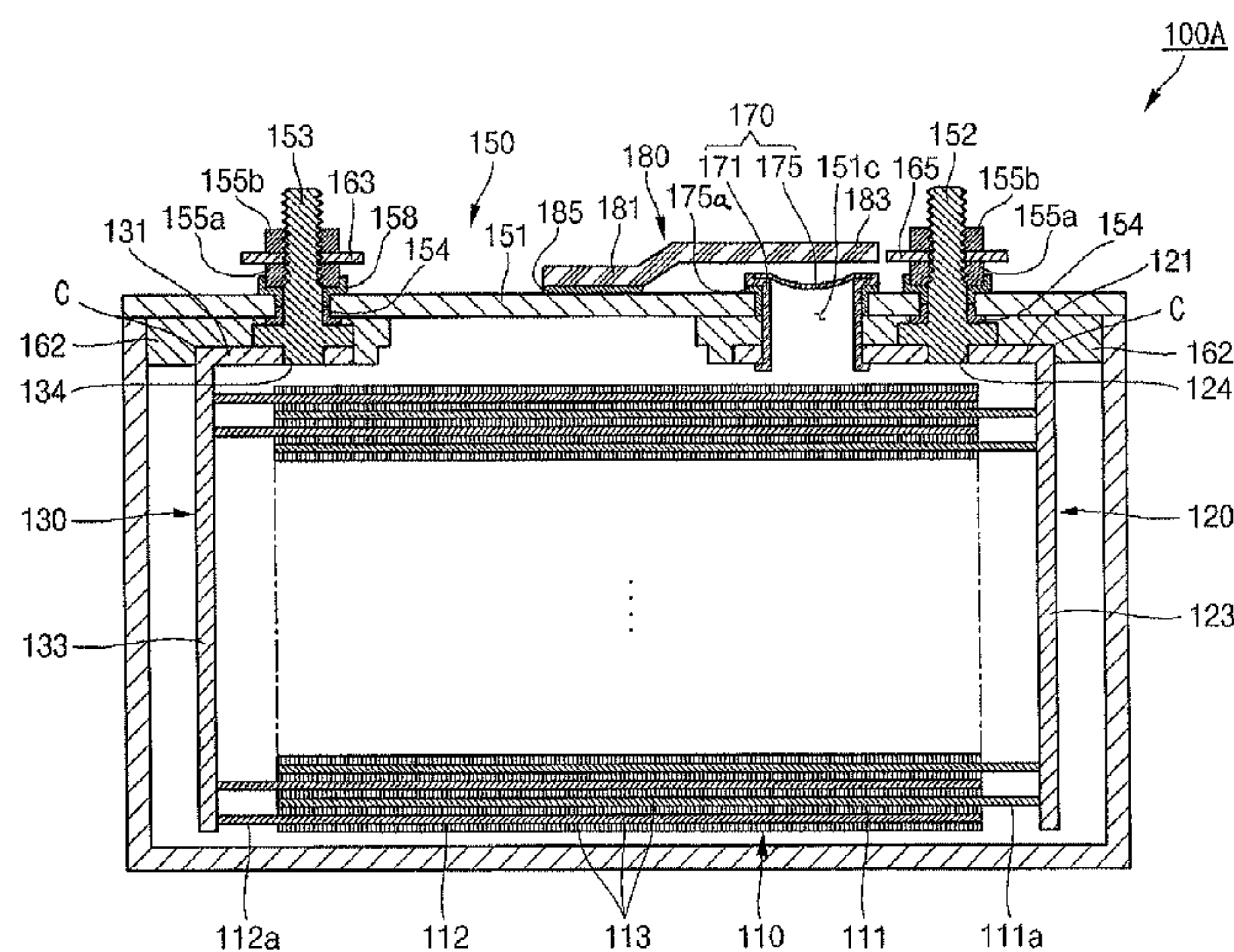


FIG. 1

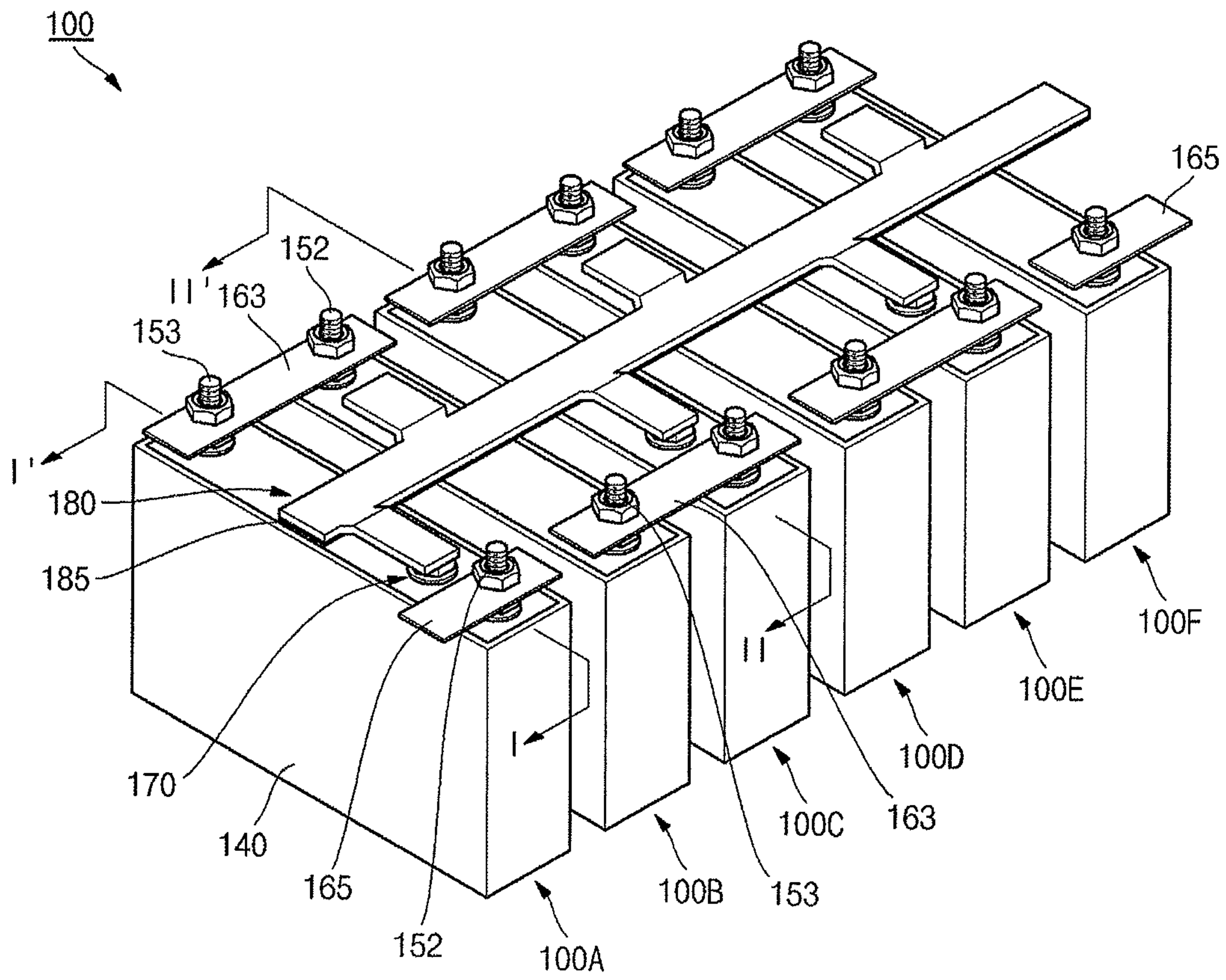




FIG. 2

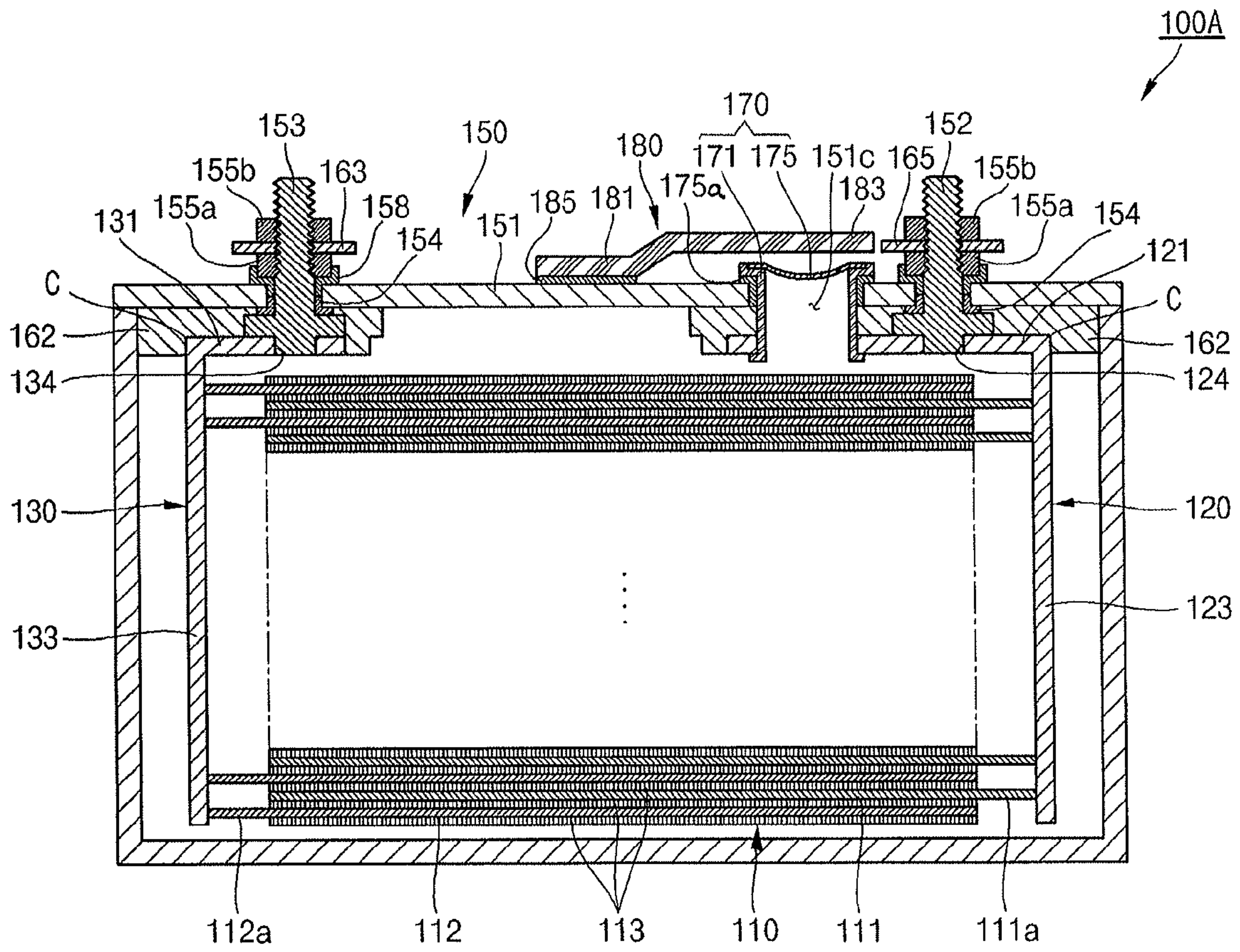


FIG. 3

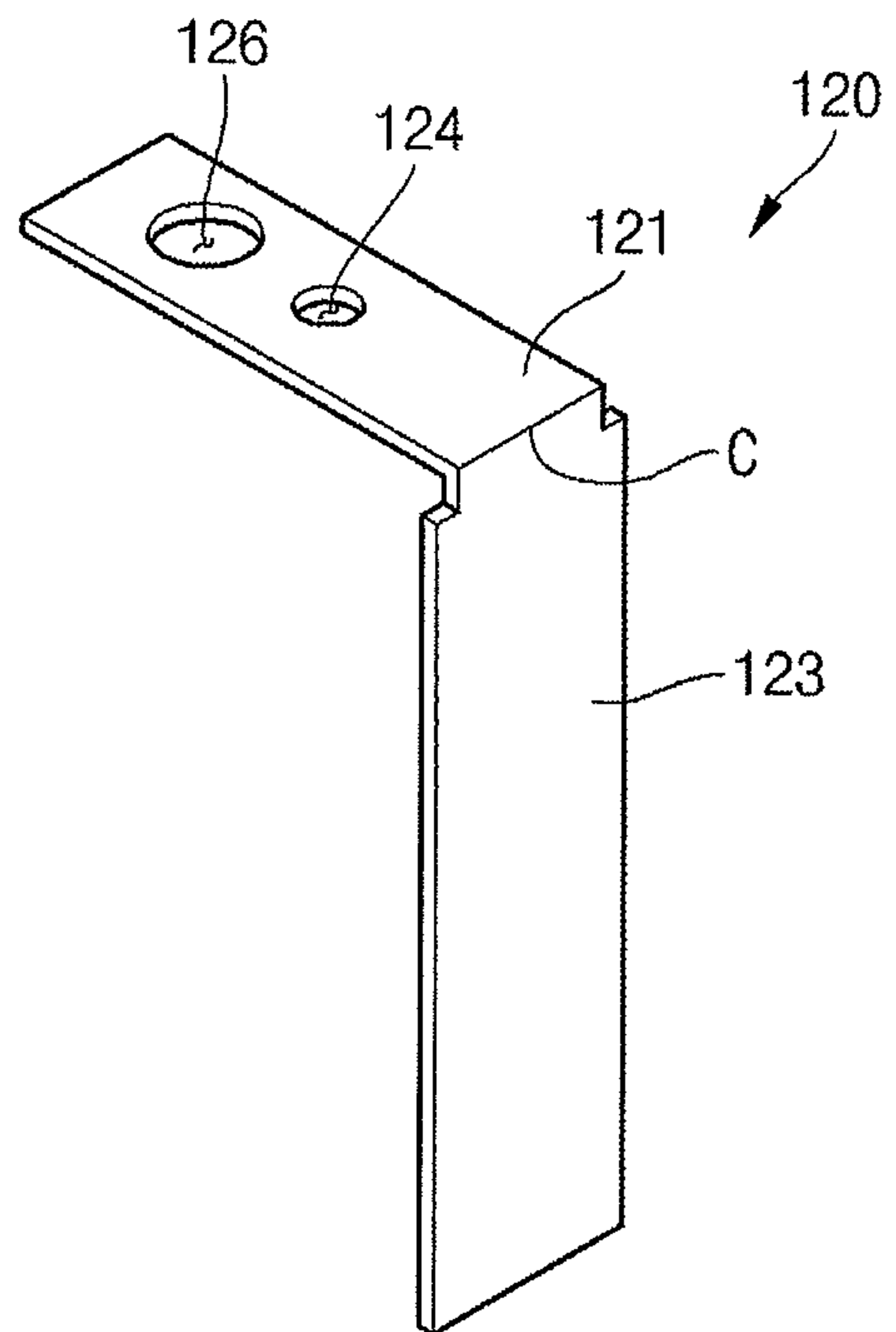


FIG. 4

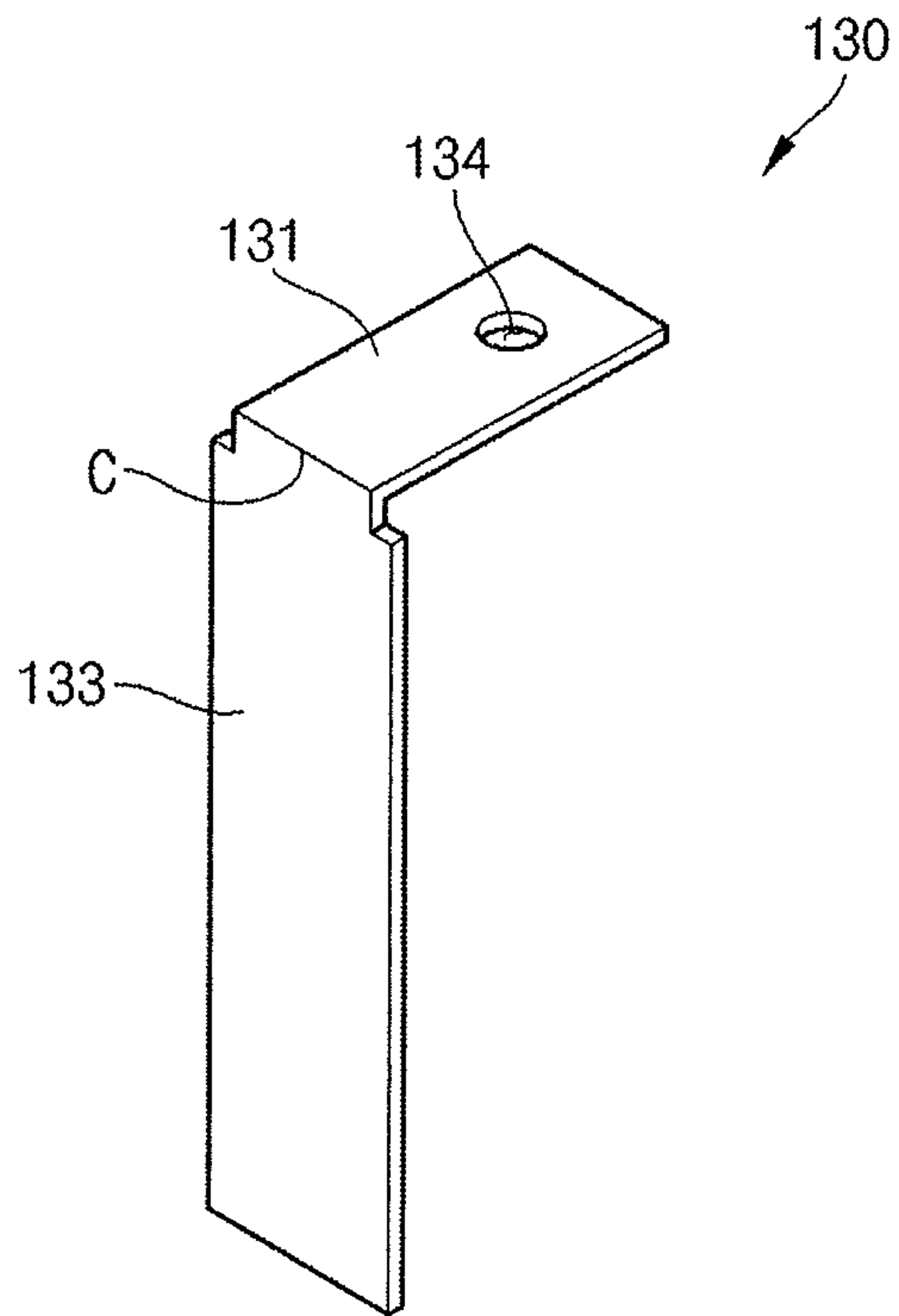


FIG. 5

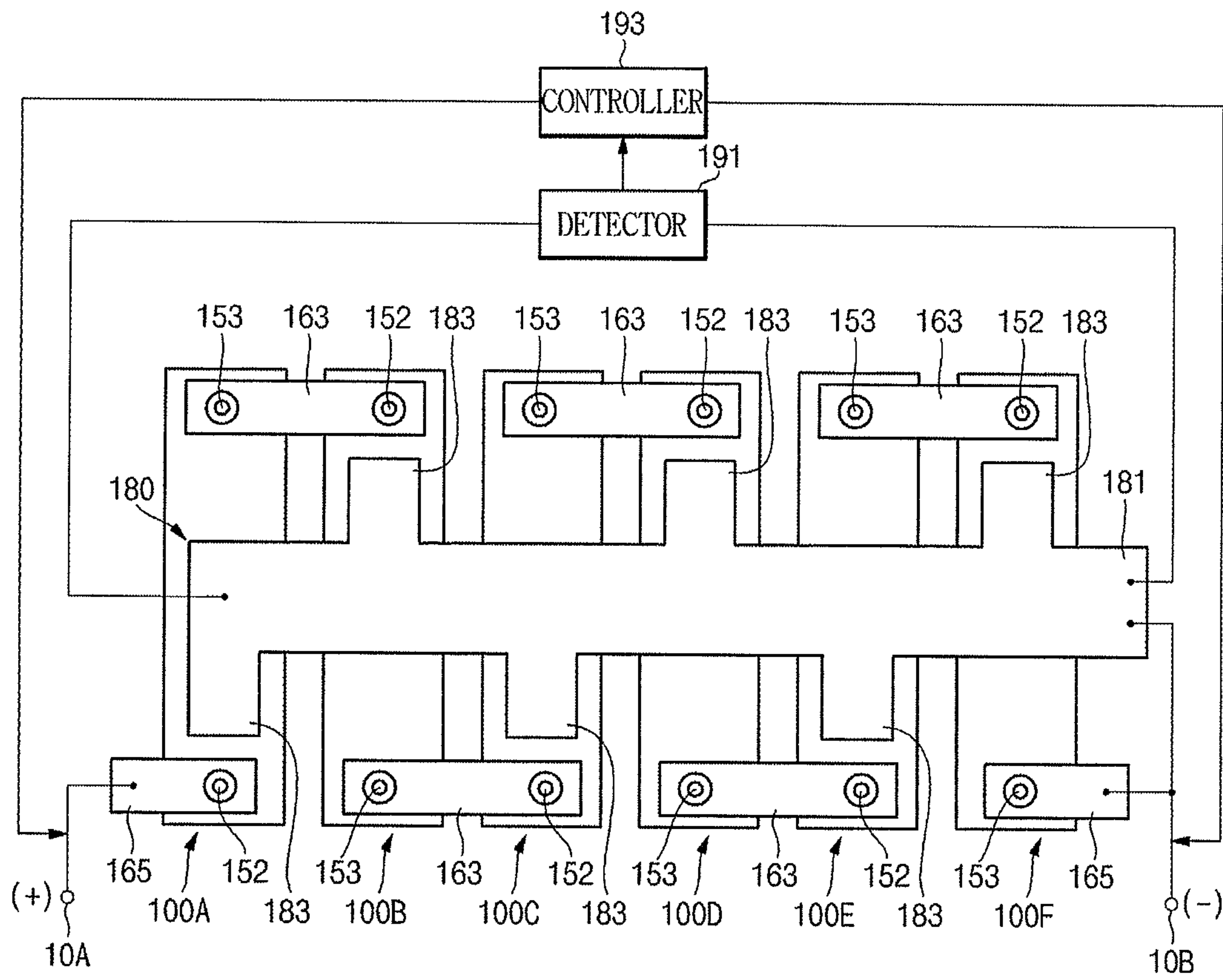


FIG. 6

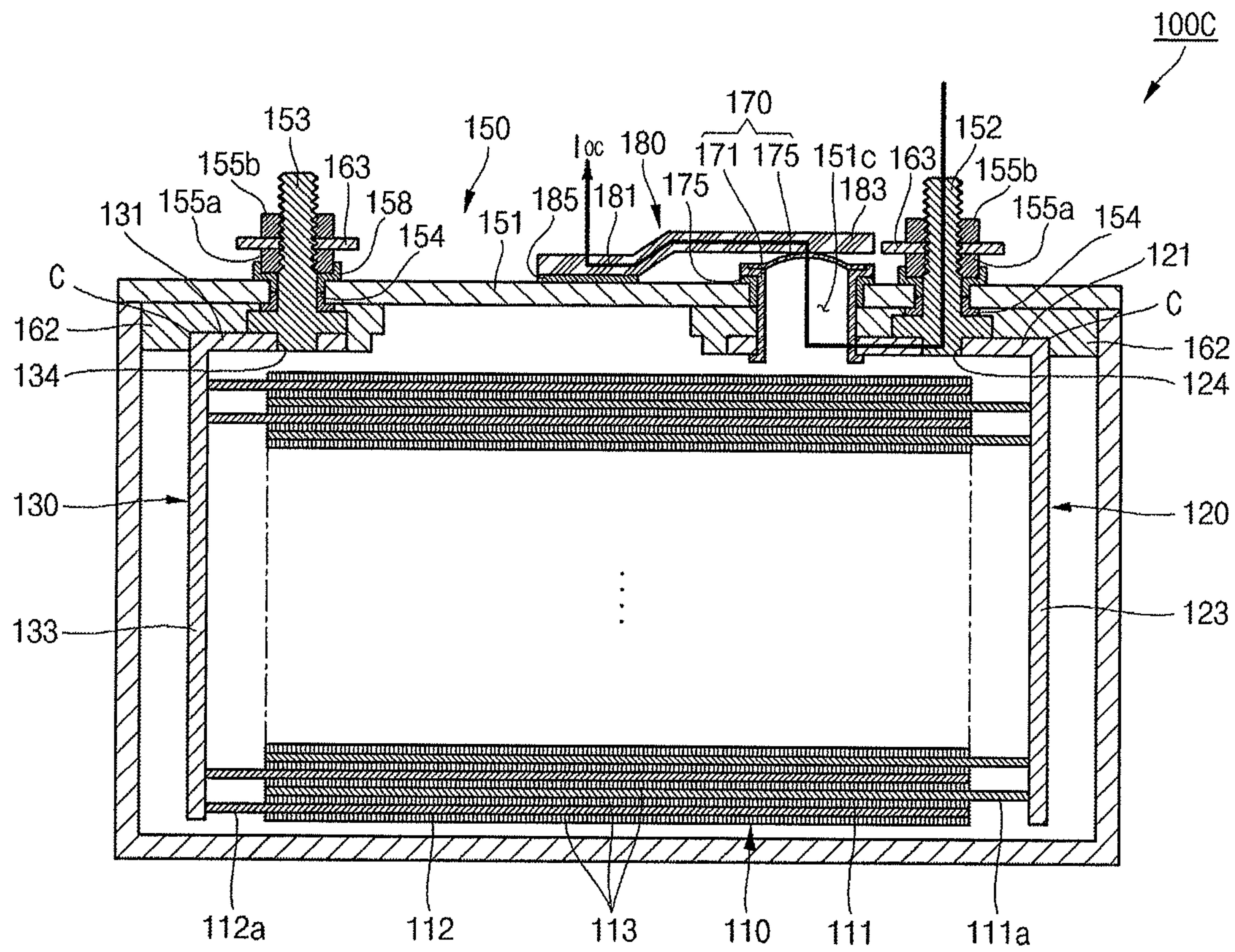
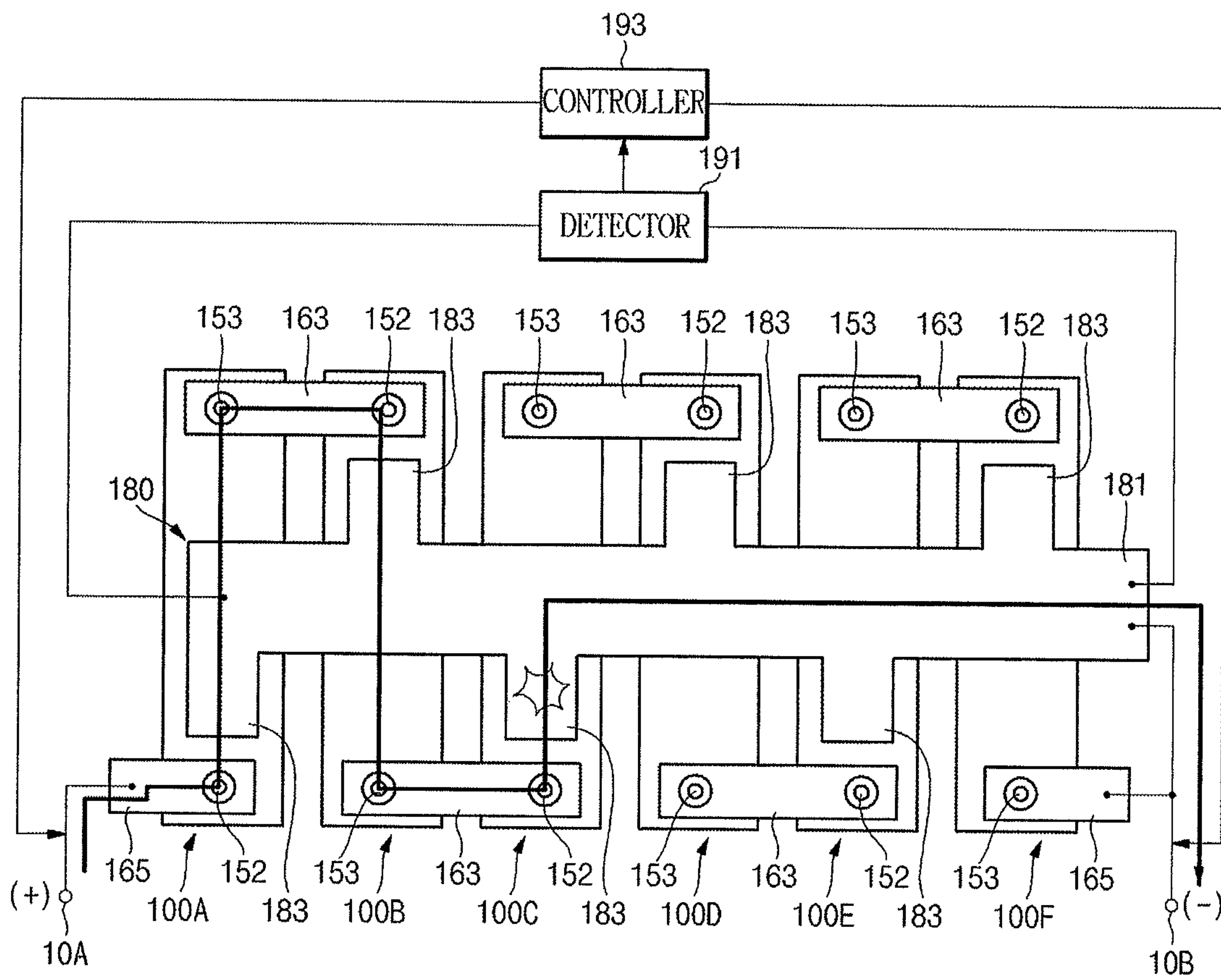




FIG. 7





## SECONDARY BATTERY MODULE WITH SHORT-CIRCUIT PROTECTOR

### BACKGROUND

A secondary battery module may include a plurality of secondary batteries connected to each other in series. Each of the secondary batteries may constitute a single unit battery. Each of the unit batteries may include an electrode assembly having a positive electrode and a negative electrode and a case accommodating the electrode assembly therein.

### SUMMARY

Embodiments may be realized by providing a secondary battery module that includes a plurality of secondary batteries, and each of the secondary batteries includes an electrode assembly, a case accommodating the electrode assembly, an electrode terminal electrically connected to the electrode assembly, and a first short-circuit member electrically connected to the electrode terminal, the first short-circuit member being configured to protrude outwardly from the case when an internal pressure of the case exceeds a preset pressure. The secondary battery module also includes a connecting member electrically connecting electrode terminals of adjacent ones of the secondary batteries, and a second short-circuit member overlapping the first short-circuit member of at least one of the plurality of secondary batteries, the second short-circuit member contacts the first short-circuit member when the first short-circuit member protrudes outwardly from the case.

The secondary battery module may include a detector that detects a voltage applied to the second short-circuit member when the first short-circuit member protrudes outwardly from the case. The secondary battery module may include a controller that controls charging of the secondary batteries according to whether the voltage is detected by the detector.

When the voltage is detected by the detector, the controller may control charging of the secondary batteries to be interrupted. The electrode assembly of each of the secondary batteries may include a first electrode plate, a second electrode plate, and a separator arranged between the first electrode plate and the second electrode plate. The electrode terminal of each of the secondary batteries may include a first electrode terminal electrically connected to the first electrode plate and a second electrode terminal electrically connected to the second electrode plate.

The first short-circuit member of each of the secondary batteries may include a pipe member having a first side electrically connected to the first electrode terminal, and the pipe member having a second side penetrating a cap plate on the case. The second side may be exposed to an outside of the case. The first short-circuit member of each of the secondary batteries may include an inversion plate covering an opening at the second side of the pipe member. The inversion plate may be configured to invert when the internal pressure exceeds the preset pressure.

Each of the secondary batteries may include a first current collector electrically connecting the first electrode plate, the first electrode terminal, and the first short-circuit member, and a second current collector electrically connecting the second electrode plate and the second electrode terminal. The first current collector may include a first connecting part connected to the first electrode terminal and the first short-circuit member. The first current collector may include a first extending part extending from the first connecting part and

coupled to the first electrode plate. The first short circuit member may be coupled to a connection hole in the first connecting part.

The first short-circuit member of each of the secondary batteries may include a pipe member having a first side coupled to the connection hole of the first connecting part. The pipe member may have a second side penetrating a cap plate on the case and the second side may be exposed to an outside of the case. The first side of the pipe member may be connected to an inside of the case through the connection hole of the first connecting part. The first short-circuit member of each of the secondary batteries may include an inversion plate covering an opening at the second side of the pipe member. The inversion plate may be configured to invert when the internal pressure exceeds the preset pressure.

The second short-circuit member may include a center part electrically connected to an external terminal, and a plurality of branch parts extending from the center part. Each of the plurality of branch parts may face the inversion plate of the first short-circuit member of a corresponding one of the plurality of secondary batteries. The second current collector of each of secondary batteries may include a second connecting part connected to the second electrode terminal, and a second extending part extending from the second connecting part and coupled to the second electrode plate of the electrode assembly.

The second short-circuit member may include a center part electrically connected to an external terminal, and a plurality of branch parts extending from the center part. Each of the plurality of branch parts may face an inversion plate of the first short-circuit member of a corresponding one of the plurality of secondary batteries. In each of secondary batteries, the electrode terminal and the first short-circuit member may be electrically insulated from the case.

The second short-circuit member may be electrically connected to an external electrode terminal of the secondary battery module. The connecting member may include a plurality of connecting members, and the connecting members may overlap opposing end regions of the secondary batteries. The second short-circuit member may overlap each of the secondary batteries along a central region of the secondary batteries, and the central region may be between the opposing end regions.

The plurality of secondary batteries may be arranged in a serial connection such that the secondary batteries are serially connected to each other. The second short-circuit member may be a by-pass route for the serial connection between the plurality of secondary batteries. When the internal pressure of the case may be below the preset pressure, the second short-circuit member may be in a non-contacting relationship with the first short-circuit member of the at least one of the plurality of secondary batteries and the first short circuit member may protrude inwardly toward the electrode assembly.

Embodiments may also be realized by providing a secondary battery module that includes a plurality of secondary batteries connected to each other in series as unit batteries, wherein abnormal ones of the plurality of secondary batteries each have an internal pressure that exceeds a preset pressure and are electrically connected to an external electrode terminal of the secondary battery module such that current flows directly from the abnormal ones of the plurality of the secondary batteries to the external electrode terminal of the secondary battery module.

Each of secondary batteries may include an electrode assembly, a case accommodating the electrode assembly, an electrode terminal electrically connected to the electrode assembly, and a first short-circuit member electrically con-



connected to the electrode terminal. The first short-circuit member may be configured to protrude outwardly from the case when an internal pressure of the case exceeds a preset pressure.

The secondary battery module may include a second short-circuit member electrically connected to the external electrode terminal of the secondary battery module. The second short-circuit member may overlap the first short-circuit member of at least one of the plurality of secondary batteries such that the second short-circuit member contacts the first short-circuit member when the first short circuit member protrudes outwardly from the case.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Features will become apparent to those of ordinary skill in the art by describing in detail exemplary embodiments with reference to the attached drawings in which:

FIG. 1 illustrates a perspective view of a secondary battery module according to an exemplary embodiment;

FIG. 2 illustrates a cross-sectional view of the secondary battery module taken along the line I-I' of FIG. 1;

FIG. 3 illustrates a perspective view of a first current collector according to an exemplary embodiment;

FIG. 4 illustrates a perspective view of a second current collector according to an exemplary embodiment;

FIG. 5 illustrates additional components of the secondary battery module with a top view of the secondary battery module shown in FIG. 1;

FIG. 6 illustrates an operation of the secondary battery module according to an exemplary embodiment in an event of overcharge along the line II-II' of FIG. 1; and

FIG. 7 illustrates a top view of an operation of the secondary battery module according to an exemplary embodiment in an event of overcharge.

#### DETAILED DESCRIPTION

Korean Patent Application No. 10-2012-0029985, filed on Mar. 23, 2012, in the Korean Intellectual Property Office, and entitled: "Secondary Battery Module," is incorporated by reference herein in its entirety.

Example embodiments will now be described more fully hereinafter with reference to the accompanying drawings; however, they may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

In the drawing figures, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer or element is referred to as being "on" another layer or substrate, it can be directly on the other layer or substrate, or intervening layers may also be present. Further, it will be understood that when a layer is referred to as being "under" another layer, it can be directly under, and one or more intervening layers may also be present. In addition, it will also be understood that when a layer is referred to as being "between" two layers, it can be the only layer between the two layers, or one or more intervening layers may also be present. Like reference numerals refer to like elements throughout.

FIG. 1 illustrates a perspective view of a secondary battery module 100 according to an exemplary embodiment, FIG. 2 illustrates a cross-sectional view of the secondary battery module 100 taken along the line I-I' of FIG. 1, FIG. 3 illustrates a perspective view of a first current collector 120

according to an exemplary embodiment, FIG. 4 illustrates a perspective view of a second current collector 130 according to an exemplary embodiment, and FIG. 5 illustrates additional components of a secondary battery module taken from a top view with respect to the secondary battery module 100 shown in FIG. 1.

Referring to FIGS. 1 to 5, the secondary battery module 100, according to an exemplary embodiment, may include a plurality of interconnected secondary batteries 100A to 100F. The secondary battery module 100 may include a first connecting member 163 connecting ones first to sixth secondary batteries 100A, 100B, 100C, 100D, 100E, and 100F to each other, e.g., the first connecting member 163 may include a plurality of first connecting members 163 that each overlap and is coupled with at least two of the first to sixth secondary batteries 100A, 100B, 100C, 100D, 100E, and 100F. The secondary battery module 100 may include a second short-circuit member 180, e.g., the second short-circuit member 180 may overlap and be coupled with each of the first to sixth secondary batteries 100A, 100B, 100C, 100D, 100E, and 100F.

The secondary battery module 100, according to an exemplary embodiment, may include the first to sixth secondary batteries 100A, 100B, 100C, 100D, 100E, and 100F as unit batteries. In the exemplary embodiment, six secondary batteries are provided for illustration only. The secondary battery module may include two or more secondary batteries as unit batteries. Each of the unit batteries may be connected in series within the secondary battery module 100.

Hereinafter, configurations of the secondary batteries, according to an exemplary embodiment, will be described. Each of the secondary batteries may have a same configuration. The configurations of the secondary batteries will now be described with regard to a first secondary battery 100A by way of example.

The first secondary battery 100A may include an electrode assembly 110, a first current collector 120, a second current collector 130, a case 140, a first electrode terminal 152 connected to the first current collector 12, a second electrode terminal 153 connected to the second current collector 130, and a first short-circuit member 170.

The electrode assembly 110 may be formed by winding or stacking a first electrode plate 111, a separator 113, and a second electrode plate 112, which may have a thin plate or film shape. The first electrode plate 111 may function as a positive electrode and the second electrode plate 112 may function as a negative electrode. Alternatively, the first electrode plate 111 and the second electrode plate 112 may function oppositely. The separator 113 may be arranged between the first and second electrode plates 111 and 112.

The first electrode plate 111 may be formed by applying a first electrode active material (such as transition metal oxide) to a first electrode current collector formed of metal foil (such as aluminum). The first electrode plate 111 may include a first electrode non-coating portion 111a to which the first electrode active metal is not applied. The first electrode non-coating portion 111a may function as a current flow passage between the first electrode plate 111 and the outside of the first electrode plate 111, e.g., a passage between the coated portions of the first electrode plate 111 and the first current collector 120. In the current embodiment, materials that may be used to form the first electrode plate 111 are not limited to the above-mentioned materials.

The second electrode plate 112 may be formed by applying a second electrode active material (such as graphite or carbon) to a second electrode current collector formed of metal foil (such as aluminum foil). The second electrode plate 112



may include a second electrode non-coating portion **112a** to which the second electrode active metal is not applied. The second electrode non-coating portion **112a** may function as a current flow passage between the second electrode plate **112** and the outside of the second electrode plate **112**, e.g., a passage between coated portions of the second electrode plate **112** and the second current collector **130**. In the current embodiment, materials that can be used to form the second electrode plate **112** are not limited to the above-mentioned materials.

The separator **113** may be located between the first electrode plate **111** and the second electrode plate **112** to reduce the possibility of and/or prevent a short circuit and to enable and/or allow movement of charge (such as lithium ions). The separator **113** may be formed of a polyethylene film, a polypropylene film, or a film including polyethylene and polypropylene. In the current embodiment, materials that can be used to form the separator **113** are not limited to the above-mentioned materials.

The first and second current collectors **120** and **130** may be coupled to both end parts of the electrode assembly **110** in a manner such that the first and second current collectors **120** and **130** may be electrically connected to the first and second electrode plates **111** and **112**, respectively. That is, the first and second current collectors **120** and **130** may be coupled to both end parts of the electrode assembly **110** in a manner such that the first and second current collectors **120** and **130** are connected to the first electrode non-coating portion **111a** of the first electrode plate **111** and the second electrode non-coating portion **112a** of the second electrode plate **112**.

The first current collector **120** may be formed of a conductive material (such as aluminum or an aluminum alloy). The first current collector **120** may make contact with the first electrode non-coating portion **111a** that protrudes from one end of the electrode assembly **110** so that the first current collector **120** may be electrically connected to the first electrode plate **111**.

The first current collector **120** may include a first connecting part **121** and a first extending part **123**, e.g., as illustrated in FIG. 3. A first terminal hole **124** and a connection hole **126** may be formed in the first connecting part **121**. The first terminal hole **124** may be spaced apart from the connection hole **126**. The first terminal hole **124** may provide a space through which the first electrode terminal **152** is fitted and coupled. The connection hole **126** may provide a space through which a first side of the first short-circuit member **170** is fitted and coupled.

The first extending part **123** may be a bent portion of the first current collector **120**, e.g., bent from the first connecting part **121**. The first extending part **123** may extend from an end of the first connecting part **121** and may be shaped as a plate making contact with the first electrode non-coating portion **111a**, e.g., making contact with each of a plurality of first electrode non-coating portions **111a**. Assuming that a corner where the first connecting part **121** and the first extending part **123** meet is denoted by C, the first connecting part **121** and the first extending part **123** may be perpendicular to each other about the corner C.

The second current collector **130** may be formed of a conductive material (such as copper, a copper alloy, nickel, or a nickel alloy). The second current collector **130** may make contact with the second electrode non-coating portion **112a** protruding to the other end of the electrode assembly **110** to be electrically connected to the second electrode plate **112**.

The second current collector **130** may include a second connecting part **131** and a second extending part **133**, e.g., as illustrated in FIG. 4. A second terminal hole **134** may be

formed in the second connecting part **131**. The second terminal hole **134** may provide a space to which the second electrode terminal **153** is fitted and coupled. The second connecting part **131** may exclude a connection hole, e.g., the connection hole **126** that has the short-circuit member **170** fitted and coupled thereto. The second extending part **133** may be bent from the second connecting part **131** and may extend from an end of the second connecting part **131**. The second extending part **133** may be shaped as a plate making contact with the second electrode non-coating portion **112a**, e.g., with each of a plurality of second electrode non-coating portions **112a**. Assuming that a corner where the second connecting part **131** and the second extending part **133** meet is denoted by C, the second connecting part **131** and the second extending part **133** may be perpendicular to each other about the corner C.

The case **140** may be formed of a conductive material (such as aluminum, an aluminum alloy, or nickel plated steel). The case **140** may have an approximately hexahedron shape with an opening so that the electrode assembly **110**, the first current collector **120**, and the second current collector **130** may be inserted and placed in the case **140**. In the illustrated embodiment the case **140** and the cap assembly **150** are shown as being coupled to each other, and the peripheral part of the cap assembly **150** substantially corresponds to the opening of the case **140**. The inner surface of the case **140** may be insulated to be electrically insulated from the electrode assembly **110**, the first current collector **120**, and the second current collector **130**. Accordingly, the case **140** may be electrically neutral.

The cap assembly **150** may be coupled to the case **140**. For example, the cap assembly **150** may include a cap plate **151**, the first electrode terminal **152**, the second electrode terminal **153**, gaskets **154**, first nuts **155a**, first upper insulation members **158**, lower insulation members **162**, and the first short-circuit member **170**.

The cap plate **151** may close the opening of the case **140** and may have a short-circuit hole **151c** formed therein. The short-circuit hole **151c** may accommodate the first short-circuit member **170**. The cap plate **151** may be formed of the same material as the case **140**. The cap plate **151** may have the same polarity as that of the case **140**. The cap plate **151** may be electrically neutral.

The first electrode terminal **152** may penetrate one side of the cap plate **151** to be electrically connected to the first current collector **120**. The first electrode terminal **152** may have a pillar shape. A thread may be formed on the outer surface of an upper pillar portion of the first electrode terminal **152**, e.g., the upper pillar portion may be on an outside of the case **140**. The first electrode terminal **152** may protrude to an upper portion of the cap plate **151**. A flange **152a** may be formed on a lower pillar portion positioned under the cap plate **151** so that the first electrode terminal **152** may not be easily separated from the cap plate **151**. The pillar portion positioned corresponding to a portion of the flange **152a** may be fitted to the first terminal hole **124** of the first current collector **120**.

The second electrode terminal **153** may penetrate another side of the cap plate **151** to be electrically connected to the second current collector **130**. The second electrode terminal **153** may have substantially the same shape as the electrode terminal **152**. Thus, descriptions thereof will not be repeated. The second electrode terminal **153** may similarly include a flange portion that is fitted to the second terminal hole **134** of the second current collector **130**.

The gaskets **154** may be formed of an insulating material. The gaskets **154** may be located between the cap plate **151**



and the first and second electrode terminals **152** and **153**, respectively. The gaskets **154** may seal gaps between the cap plate **151** and the first and second electrode terminals **152** and **153**, respectively. The gaskets **154** may reduce the possibility of and/or prevent permeation of moisture into the secondary battery **100A** and/or leakage of electrolyte from the inside of the secondary battery **100A** to an outside of the secondary battery **100A**.

The first upper insulation members **158** may be located between the cap plate **151** and the first and second electrode terminals **152** and **153**, respectively. The first upper insulation members **158** may allow the first and second electrode terminals **152** and **153**, respectively, to be fitted to the cap plate **151**. The first upper insulation members **158** may make tight contact with the cap plate **151** and with the gaskets **154**, e.g., in an area through which the first and second electrode terminals **152** and **153** extend through the cap plate **151**. The first upper insulation members **158** may insulate the cap plate **151** from the first and second electrode terminals **152** and **153**, respectively.

The first nuts **155a** may be fastened along the threads formed in the first electrode terminal **152** and the second electrode terminal **153**, e.g., to fix the first electrode terminal **152** and the second electrode terminal **153** to the cap plate **151**.

The lower insulation members **162** may be located between the cap plate **151** and the first and second current collectors **120** and **130**, respectively. The lower insulation members **162** may reduce the possibility of and/or prevent an unnecessary short circuit.

The first short-circuit member **170** may include a pipe member **171** and an inversion plate **175**.

The pipe member **171** may have a continuous shape such as a substantially cylindrical pipe shape, e.g., so as to be formed along sidewalls of various openings. A first side of the pipe member **171**, e.g., a lower portion of the pipe member **171**, may be fastened to the connection hole **126** of the first current collector **120** to be connected, e.g., electrically connected, to the first electrode terminal **152**. For example, the first side of the pipe member **171** may be coupled to the connection hole **126** of the first current collector **120** by a rivet, e.g., a lowermost portion of the pipe member **171** may be in contact with a surface of the first current collector **120** that faces the electrode assembly **110**. The pipe member **171** may be connected to the inside of the case **140** through the connection hole **126** of the first current collector **120**.

A second side of the pipe member **171**, e.g., an upper portion of the pipe member **171**, may be exposed to an upper portion of the cap plate **151**, e.g., may be exposed to the outside of the case **140**. The second side of the pipe member **171** may penetrate, e.g., extend through, a short circuit hole **151c** of the cap plate **151**. The second side of the pipe member **171** may also extend through one of the lower insulation members **162**.

A second upper insulation member **175a** may be formed between the second side of the pipe member **171** and the short circuit hole **151c** of the cap plate **151**. Accordingly, the pipe member **171** and the cap plate **151** may be electrically insulated from each other. The second upper insulation member **175a** may be on one of the lower insulation members **162**.

The inversion plate **175** may cover an opening, e.g., a center portion, of the second side of the pipe member **171**. The inversion plate **175** may be electrically connected to the pipe member **171**. The inversion plate **175** may have a downwardly convex round part (e.g., forming a lowermost portion of the inversion plate **175** that corresponds to approximately a center of the pipe member **171**) and an edge part (e.g.,

forming uppermost support portions of the inversion plate **175**) fixed to a top end of the second side of the pipe member **171**. The inversion plate **175** may be a semi-flexible element. Without intending to be bound by this theory, when the internal pressure of the case **140** exceeds a preset pressure (e.g., due to overcharge, penetration, and/or external short circuit occurring to the secondary battery) the inversion plate **175** may be inverted and protrude upward. For example, the convex round part may move upward to form a concave round part being an uppermost portion of the inversion plate **175**.

Referring to FIG. 1, the first connecting member **163** may electrically connect electrode terminals of adjacent secondary batteries among the first to sixth secondary batteries **100A**, **100B**, **100C**, **100D**, **100E**, and **100F**. The first connecting member **163** may have a substantially plate-like shape and two holes may be formed therein, e.g., the holes may be formed on opposing ends. The two holes may each be fitted to an electrode terminal of adjacent secondary batteries having different polarities. Therefore, the first connecting member **163** may connect the adjacent secondary batteries to each other in series. A second nut **155b** may be fastened to the electrode terminal to which the first connecting member **163** is fitted along the thread of the electrode terminal to fix the first connecting member **163** to the electrode terminal. The first connecting member **163** may include a plurality of first connecting members **163** arranged on opposing sides of the first to sixth secondary batteries **100A**, **100B**, **100C**, **100D**, **100E**, and **100F**, and the second short-circuit member **180** may be arranged between the plurality of first connecting members **163**.

The secondary battery module **100** may further include a second connecting member **165** connecting the first to sixth secondary batteries **100A**, **100B**, **100C**, **100D**, **100E**, and **100F** connected to each other in series to external electrode terminals **10A** and **10B**, e.g., as illustrated in FIG. 5. The second connecting member **165** may be connected to the highest and lowest potential electrode terminals of the secondary batteries among the first to sixth secondary batteries **100A**, **100B**, **100C**, **100D**, **100E**, and **100F** connected to each other in series.

According to an exemplary embodiment, the second connecting member **165** may electrically connect the highest potential electrode terminal to the external positive electrode terminal **10A**. The second connecting member **165** may electrically connect the lowest potential electrode terminal to the external positive electrode terminal **10B**. The second connecting member **165** may have substantially the same shape as the first connecting member **163**. The second connecting member **165** may only be coupled with one of the electrode terminals instead of two of the electrode terminals like the first connecting member **163**. However, the current embodiment is not limited to such a shape, and the second connecting member **165** may have various shapes.

The second short-circuit member **180** may be electrically connected to the external terminals, e.g., to the external electrode terminals **10A** and **10B**. The second short-circuit member **180** may be arranged to face the inversion plate **175** of the first short-circuit member **170**, e.g., the second short circuit member **180** may face each or at least one of the inversion plates **175** of the first to sixth secondary batteries **100A**, **100B**, **100C**, **100D**, **100E**, and **100F**. The second short-circuit member **180** may overlap the inversion plate **175** and may not be in contact therewith when the inversion plate **175** has the convex shape extending toward the inside of the case **140**. The second short-circuit member **180** may make contact with the inversion plate **175** when the inversion plate **175** has been inverted and protrudes toward the outside of the case **140**.



The second short-circuit member **180** may include a center part **181** and a plurality of branch parts **183**. The center part **181** may be formed shaped as a bar and may be electrically connected to the external negative electrode terminal **10B**. The center part **181** may be disposed above, e.g., in an overlapping relationship, with each of the first to sixth secondary batteries **100A**, **100B**, **100C**, **100D**, **100E**, and **100F**. An insulation plate **185** may be formed under the center part **181**, e.g., on a bottom surface of the center part **181**. The insulation plate **185** may reduce the possibility of and/or prevent an unnecessary short circuit between the second short-circuit member **180** and the cap plate **151**. The insulation plate **185** may be excluded under the plurality of branch parts **183**.

The plurality of branch parts **183** may extend from opposing sides of the center part **181**, e.g., portions of the branch parts **183** may extend at an upward angle from the center part **181** toward the first connecting members **163**. The plurality of branch parts **183** may be arranged to be spaced a predetermined distance apart from inversion plates **175** of the first short-circuit members **170**, while still overlapping the inversion plates **175**. For example, each branch part **183** may have a lower surface that faces the inversion plate **175** of one of the first to sixth secondary batteries **100A**, **100B**, **100C**, **100D**, **100E**, and **100F**. The predetermined distance between the plurality of branch parts **183** and the inversion plates **175** of the first short-circuit members **170** may be large enough to allow the protruding inversion plates **175** to make contact with the plurality of branch parts when the inversion plates **175** of the first short-circuit members **170** are inverted and protrude toward an outside of the case **140**.

The secondary battery module **100** may further include a detector **191** and a controller **193**. The detector **191** may be connected to the second short-circuit member **180** to detect a voltage of the second short-circuit member **180**. The controller **193** may control charging of the secondary battery module **100** according to whether the voltage of the second short-circuit member **180** is detected by the detector **191**. Configurations of the detector **191** and the controller **193** will be described below in detail when describing the operation of the secondary battery module **100**.

Hereinafter, the operation of the secondary battery module **100** in an event of overcharge will be described in detail.

FIGS. **6** and **7** illustrate the operation of the secondary battery module **100** according to an exemplary embodiment in an event of overcharge. First, before describing the operation of the secondary battery module **100**, it is assumed that overcharge occurs to an arbitrary secondary battery among the first to sixth secondary batteries **100A**, **100B**, **100C**, **100D**, **100E**, and **100F**. For example, it is assumed that overcharge occurs at the third secondary battery **100C**. Accordingly, FIG. **6** illustrates an exemplary event of overcharge along the line II-II' of FIG. **1**.

As assumed above, when overcharge occurs to the third secondary battery **100C**, the internal pressure of the case **140** of the third secondary battery **100C** increases. Here, if the internal pressure of the case **140** of the third secondary battery **100C** exceeds a preset pressure, the inversion plate **175** of the first short-circuit member **170** may be inverted to protrude to the outside of the case **140**, as shown in FIG. **6**. The inversion plate **175** of the first short-circuit member **170** may make electrical contact with the corresponding one of branch parts **183** of the second short-circuit member **180** facing the inversion plate **175** of the first short-circuit member **170**.

Accordingly, as shown in FIGS. **6** and **7**, over-current generated from the third secondary battery **100C** due to overcharge may directly flow to the external negative electrode terminal **10B** through the first short-circuit member **170** and

the second short-circuit member **180**, rather than other secondary batteries such as the fourth to sixth secondary batteries **100D**, **100E**, and **100F**. Accordingly, the second short-circuit member **180** may provide a by-pass route for the over-current so that the over-current may by-pass the other secondary batteries, e.g., the fourth to sixth secondary batteries **100D**, **100E**, and **100F**.

When the overcharge occurs to the secondary battery module **100**, over-current may flow through the second short-circuit member **180** and the detector **191** may detect a voltage from the second short-circuit member **180**. Then, an overcharge notice signal may be transmitted to the controller **193** to notify the controller **193** that the voltage has been detected from the second short-circuit member **180**. The controller **193** may control charging of the secondary battery module **100** to be interrupted in response to the overcharge notice signal received from the detector **191**. For example, the controller **193** may physically or electrically disconnect the external electrode terminals **10A** and **10B** and the secondary batteries.

According to the exemplary embodiments, when overcharge occurs to an arbitrary secondary battery among the plurality of secondary batteries connected to each other in series, over-current generated from the overcharged secondary battery may flow to the external electrode terminal through the first short-circuit member **170** and the second short-circuit member **180**, rather than to the next secondary battery adjacent to the overcharged battery. Therefore, the other batteries may be protected from being damaged. Accordingly, the fail-safe function and stability of the secondary battery module may be improved.

In addition, the same effect may be demonstrated in an event of penetration and/or external short circuit as well as overcharge of battery. Further, it is may not be necessary to provide a fuse in each secondary battery, the secondary battery may have improved durability.

By way of summation and review, unit batteries may each include a case accommodating an electrode assembly, a cap assembly coupled to the case and sealing the case, and positive and negative electrode terminals protruding through the cap assembly and electrically connected to current collectors of positive and negative electrodes of the electrode assembly. The respective unit batteries may together constitute a secondary battery module, which is a large-capacity battery module, by connecting the positive and negative electrode terminals of adjacent unit batteries using a bus bar.

The secondary battery module may have electrode terminals in forms of external threads. Further, the respective unit batteries may be connected to each other in series so that bus bars as conductor are inserted into positive electrode terminals of ones of the unit batteries and negative electrode terminals of adjacent unit batteries. Fastening nuts may be fastened to the terminals and the bus bar may be fixed within the secondary battery module.

Since the respective unit batteries are connected to each other in series, in an event of overcharge, penetration, and/or external short-circuit occurring to any one of the unit batteries, over-current may flow from the unit battery undergoing the event (e.g., of overcharge, penetration, and/or external short-circuit) to the last connected unit battery, resulting in damage being caused to other unit batteries that did not undergo the event.

In contrast, embodiments relate to providing a secondary battery module having improved fail-safe function and stability to an event such as overcharge, penetration, and/or external short-circuit in one of the unit batteries.

Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to



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be interpreted in a generic and descriptive sense only and not for purpose of limitation. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

What is claimed is:

1. A secondary battery module, comprising:
  - a plurality of secondary batteries, each of the secondary batteries including an electrode assembly, a case accommodating the electrode assembly, an electrode terminal electrically connected to the electrode assembly, and a first short-circuit area electrically connected to the electrode terminal, the first short-circuit area including:
    - (a) a surface to protrude outwardly relative to the case when an internal pressure of the case exceeds a preset pressure, and
    - (b) a pipe to direct the internal pressure toward the surface; a connector electrically connecting electrode terminals of adjacent ones of the secondary batteries; and
    - a second short-circuit area overlapping the first short-circuit area of at least one of the plurality of secondary batteries, the second short-circuit area contacting the first short-circuit area when the first short-circuit member protrudes outwardly relative to the case.
2. The secondary battery module as claimed in claim 1, further comprising a detector that detects a voltage applied to the second short-circuit area when the first short-circuit area protrudes outwardly relative to the case.
3. The secondary battery module as claimed in claim 2, further comprising a controller that controls charging of the secondary batteries according to whether the voltage is detected by the detector.
4. The secondary battery module as claimed in claim 3, wherein, when the voltage is detected by the detector, the controller controls charging of the secondary batteries to be interrupted.
5. The secondary battery module as claimed in claim 1, wherein:
  - the electrode assembly of each of the secondary batteries includes a first electrode plate, a second electrode plate, and a separator arranged between the first electrode plate and the second electrode plate, and
  - the electrode terminal of each of the secondary batteries includes a first electrode terminal electrically connected to the first electrode plate and a second electrode terminal electrically connected to the second electrode plate.
6. The secondary battery module as claimed in claim 1, wherein:
  - the pipe has a first side electrically connected to the first electrode terminal and a second side penetrating a cap plate on the case, the second side being exposed outside of the case, and
  - the surface includes an inversion plate covering an opening at the second side of the pipe, the inversion plate to invert when the internal pressure exceeds the preset pressure.
7. The secondary battery module as claimed in claim 5, wherein each of the secondary batteries includes:
  - a first current collector electrically connecting the first electrode plate, the first electrode terminal, and the first short-circuit area, and
  - a second current collector electrically connecting the second electrode plate and the second electrode terminal.
8. The secondary battery module as claimed in claim 7, wherein:
  - the first current collector includes a first connecting surface connected to the first electrode terminal and the first

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- short-circuit area, and the first current collector includes a first extending surface extending from the first connecting surface and coupled to the first electrode plate, and
- the first short-circuit area is coupled to a connection hole in the first connecting surface.
9. The secondary battery module as claimed in claim 8, wherein:
  - the pipe has a first side coupled to the connection hole of the first connecting surface and a second side penetrating a cap plate on the case, the second side being exposed to an outside of the case,
  - the first side of the pipe is connected to an inside of the case through the connection hole of the first connecting surface, and
  - the surface of the first short-circuit area includes an inversion plate covering an opening at the second side of the pipe, the inversion plate to invert when the internal pressure exceeds the preset pressure.
10. The secondary battery module as claimed in claim 9, wherein the second short-circuit area includes:
  - a center surface electrically connected to an external terminal, and
  - a plurality of branch parts extending from the center surface, each of the plurality of branch parts facing the inversion plate of the first short-circuit area of a corresponding one of the plurality of secondary batteries.
11. The secondary battery module as claimed in claim 7, wherein the second current collector of each of secondary batteries includes:
  - a second connecting surface connected to the second electrode terminal, and
  - a second extending surface extending from the second connecting surface and coupled to the second electrode plate of the electrode assembly.
12. The secondary battery module as claimed in claim 1, wherein the second short-circuit area includes:
  - a center surface electrically connected to an external terminal, and
  - a plurality of branch parts extending from the center surface, each of the plurality of branch parts facing an inversion plate of the first short-circuit area of a corresponding one of the plurality of secondary batteries.
13. The secondary battery module as claimed in claim 1, wherein, in each of secondary batteries, the electrode terminal and the first short-circuit area are electrically insulated from the case.
14. The secondary battery module as claimed in claim 1, wherein the second short-circuit area is electrically connected to an external electrode terminal of the secondary battery module.
15. The secondary battery module as claimed in claim 1, wherein:
  - the connector includes a plurality of connecting members, the connecting members overlapping opposing end regions of the secondary batteries, and
  - the second short-circuit area overlaps each of the secondary batteries along a central region of the secondary batteries, the central region being between the opposing end regions.
16. The secondary battery module as claimed in claim 1, wherein:
  - the plurality of secondary batteries are arranged in a serial connection such that the secondary batteries are serially connected to each other, and
  - the second short-circuit area is a by-pass route for the serial connection between the plurality of secondary batteries.

17. The secondary battery module as claimed in claim 1, wherein, when the internal pressure of the case is below the preset pressure, the second short-circuit area is in a non-contacting relationship with the first short-circuit area of the at least one of the plurality of secondary batteries and the first short-circuit area protrudes inwardly toward the electrode assembly. 5

18. The secondary battery module as claimed in claim 1, wherein the surface of the first short-circuit area contacts the second short-circuit area when the internal pressure exceeds the preset pressure. 10

19. The secondary battery module as claimed in claim 1, wherein a length of the pipe is greater than a thickness of the case.

20. The secondary battery module as claimed in claim 1, wherein the second short-circuit area is spaced from the electrode terminal. 15

21. The secondary battery module as claimed in claim 1, wherein the surface is outside the case when the internal pressure of the case be below the preset pressure. 20

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